- Whenever feasible, existing trees within the alignment should be left in place. All trees to be removed should be clearly marked on the project plan sheets.

- Project should include implementation of the developed revegetation plan which replaces removed vegetation in such a quantity/quality that equals or exceeds that of vegetation removed.

- In-channel construction activities should be limited to the summer low-precipitation period (August 1st – October 15th) to reduce the potential for impacts on aquatic and species, nesting birds, and water quality.

- Large trees (6-12" diameter) should be inspected prior to removal for the presence of Cooper's hawk, silver-haired bat, hoary bat, or any other bird or bat nesting or roosting sites. If nest or roosting sites are found, an approved biologist should be employed to determine and implement appropriate relocation procedures.

- Herpetological exclusion fencing should be erected around the perimeter of the work area prior to construction initiation. Fencing should remain until work in sensitive areas is complete.

These recommended sensitive species avoidance measures are considered to be in addition to any best management practices, stormwater pollution protection programs, or other construction phase impact prevention measures determined to be required as part of the project. Implementation of these measures will ensure that the project has minimal impacts on the biological resources occurring at the project reach.

SECTION 4. HYDRAULIC ANALYSIS

A feasibility level hydraulic analysis consists of two primary steps: 1) analysis of existing conditions to determine site constraints and 2) prediction of likely impacts of bank stabilization to local flooding, hydraulics, and downstream erosion problems. This section presents the results of the hydraulic model runs for existing conditions along Chimes Creek and outlines the hydraulic and geomorphic constraints for bank stabilization alternatives.

The 2009 Chimes Creek topographic basemap (**Sheets 1 & 2**) was used to guide selection of cross-section locations throughout the project site. Cross-sections were selected based on proximity to known erosion sites, position in the longitudinal profile, and planform location. Cross section geometry was used with HEC-RAS (Hydrologic Engineering Center River Analysis System) hydraulic modeling software developed by the US Army Corps of Engineers to predict pertinent hydraulic variables such as velocity, depth, and shear stress. The HEC-RAS model was completed for five recurrence flow profiles: the 2-year, or Q2, Q10, Q25, and Q100 which were based on the published Balance Hydrologics report. For each event Balance Hydrologics' flow values were scaled up by 10% to provide a conservative estimate of flows in the channel and to account for additional uncertainty in watershed area and drainage system performance (**Table 7**). For each cross-section, average flow velocity, water surface elevation and shear stress were calculated.

Methods

- **1D Hydraulic Model**

HEC-RAS is a one-dimensional hydraulic model capable of calculating water surface profiles for steady gradually varied flow. The basic computational procedure is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning's n coefficient) and contraction/expansion (coefficient multiplied by the change in velocity head). This hydraulic analysis was performed with the assumption that flow in Chimes Creek is uniform, steady, and either sub or supercritical open channel flow.

- **Cross-section Geometry**

Surface information created in AutoCAD Civil 3D and topography along selected cross sections was extracted from the topographic surface using the HEC-RAS extension in AutoCAD. Stream centerline, cross-sections, and bank stations were imported into the hydraulic model.

A total of 23 cross-sections ranging from 50 to 100 feet wide were used in the analysis. Average cross-section spacing was 50 ft. To maintain consistency with the project basemap and bank inventory analysis the downstream culvert entrance was stationed at 0+00. Thus, all cross-section river stations were positive and increased moving upstream in the model.

- **Roughness**

Roughness coefficients were assigned to left overbank, channel, and right overbank sections of each cross-section. **Table 7** shows Manning's n values for various project reach lengths.

- **Steady flow analysis**

The steady flow analysis requires the input of user-defined profiles specifying peak flow data, and model boundary conditions. Flow data was taken from the Balance Hydrologic Report and increased by 10% to be conservative (See Section 1 "Hydrology"). In a modeled flow regime, boundary conditions are necessary at the upstream and downstream ends of the river system. This analysis used a "Normal Depth" boundary condition. This requires an energy slope to be used in calculating normal depth (Manning's equation) at each cross-section for each profile. Since the energy slope was unknown, the average slope of the channel at the upstream and downstream boundaries of 0.006 was used in this analysis.

Table 7

Peak Flows Used in Alternative Analysis

Profile Name	Recurrence Interval (yr)	% Exceedance Probability	Discharge (cfs)
Q2	2	50	120
Q10	10	10	191
Q25	25	4	194
Q100	100	1	198

Table 8

Manning's n Roughness Coefficients

River Station	Left Bank	n	Channel	n	Right Bank	n
0+00-2+00	Berry bushes; Riparian brush.	0.07	Sand-gravel bottom; vegetated slopes	0.050	Berry bushes; Ivy; Scattered trees	0.08
2+00-4+00	Grass lawn cover; scattered trees	0.06	Sand-gravel bottom; vegetated slopes	0.050	Berry bushes; Riparian brush.	0.07
4+00-7+00	Berry bushes; Riparian brush; scattered trees	0.08	Sand-gravel bottom; vegetated slopes	0.050	Berry bushes; Riparian brush; scattered trees	0.08
7+00-11+00	Grass; Berry bushes, Scattered trees	0.07	Sand-gravel bottom; vegetated slopes	0.050	Grass; Berry bushes, Scattered trees	0.07

Results

Flow velocity, water depth, and water surface elevation are discussed below separately for each profile. For all modeled scenarios a general pattern of maximum velocity prevails throughout the project reach (**Figure 5**). Maximum velocity patterns are caused by channel constrictions, meander bends, and knickpoints and were predicted near major erosion sites described in the geomorphic analysis (**Table 9**). The model output parameters for all profiles are included in **Appendix A**.

Table 9

Locations of Maximum Velocity

STA	Channel Feature	Erosion
68	Constriction, Meander Bend	Bank Failure, Mass Wasting
145	Knickpoint, Constriction	Vertical Incision, Bank Undercutting
181	Meander Bend	None Observed
293	Constriction	Bank Failure, Bank Undercutting
478	Constriction	Bank Failure
700	Knickpoint	Rotational Slump, Toe Erosion

- **Q2** Profile

Peak flow with a recurrence interval of two years is often considered "bankfull flow," meaning the flow that is primarily responsible for the delineation or shaping of stream beds and banks (Leopold and Wolman, 1957). The evaluation of the 2-year flow is often also considered ordinary high water (OHW) by the Corps of Engineers for purposes of establishing Corps jurisdiction over Water of the United States and construction permitting. We consider this flow, 120 cubic feet per second (cfs), as the low flow discharge in this analysis. When run through the hydraulic model, only two cross sections, STA 9+84 and 8+27 were predicted to flood during Q2 flows. In each case flow returns to the channel before the next cross section with flood depths of ~0.2 ft on the right for STA 9+84 and on the left for STA 8+27. For all other cross sections Q2 flows remained confined to the existing top of bank. Cross-section channel velocities averaged 6.1 feet per second (fps) and ranged from 2.7 to 16.3 fps, with the highest velocities occurring over existing knickpoints (**Figure 5**). Water depths averaged 2.4 ft and ranged from 0.9 to 3.9 ft. Water surface elevations are plotted in **Figure 6** and ranged from 241.6 to 213.6 ft at the ACFCD culvert.

- **Q10** Profile

The Q 10 flow has a 10% chance of occurring in any given year. Model results for this profile, 191 cfs, showed flooding in the upper section of the study reach between the Chimes Creek culvert outfall (STA 11+31) to STA 10+76. Minor and shallow (<0.5 ft) flooding was predicted on both sides of the creek with flow returning to the channel by STA 9+84. Between

STA 9+06 and 7+71 flood waters are predicted to extend laterally up to 34 ft outside the channel on river left and up to 8 ft on river right. Depth in the flooded area ranged from 0.14 ft to 0.37 ft and 0.3 ft to 0.45 ft in the left and right floodplains, respectively. Velocity ranged from 0.37 fps to 0.74 fps in the left floodplain and from 0.6 fps to 1.7 fps in the right floodplain. Shear stress in the floodplains ranged from 0.04 lb/ft^2 to 0.52 lb/ft^2. Cross-section channel velocities averaged 6.9 fps and ranged from 3 fps to 17.5 fps, with the maximum velocity occurring near the knickpoint at STA 7+00 (**Figure 5**). Water depths averaged 3 ft and ranged from 1.2 ft to 4.2 ft. Water surface elevations are plotted in **Figure 6** and ranged from 242.7 ft to 214.5 ft at the downstream boundary.

- **Q25** Profile

The Q25 flow has a 4% chance of occurring in any given year. Model results for this profile, 194 cfs, were similar to the Q10 profile however the extent and magnitude of flooding increased in some locations. Flood depths between the Chimes Creek culvert outfall and STA 10+76 on river left increased by less than 0.02 ft. Flooding on river right was predicted from STA 11+31 to STA 9+06 with an average depth ranging from 0.32 ft to 0.46 ft. Between STA 9+06 and STA 7+71 flood depths increased by 0.02 feet from the Q10 flow for both sides of the channel. Similar to the Q10 predictions, lateral flooding extended up to 34 ft on river left with a maximum depth and velocity of 0.46 ft and 1.7 fps, respectively. Increased flooding was predicted at STA 7+71 on river right with an average velocity of 0.1 fps. Shear stress in the floodplains ranged from 0.02 lb/ft^2 to 0.54 lb/ft^2. Flow in the lower section of Chimes Creek is completely within the existing top of bank. Cross-section channel velocities for the entire reach averaged 6.9 fps and ranged from 3.0 to 17.5 fps. Depths averaged 2.6 ft and ranged from 1.2 to 4.2 ft. Shear stress in the channel ranged from 0.53 lb/ft^2 to 21.4 lb/ft^2 with the highest average channel shear stress occurring near existing knickpoints and in the lower project reach where slope has a dominating effect on sediment transport. Water surface elevations are plotted in **Figure 6** and ranged from 242.7 to 214.6 ft.

- **Q100** Profile

Model results for the 100-year flood of 198 cfs follow the same pattern of the Q10 and Q25 flow events with flooding between STA 9+84 and 7+71. In this area flood waters extend up to 34 ft outside the channel on river left with depth and velocity ranging from 0.03 ft to 0.42 ft and 0.21 fps and 0.65 fps, respectively. Average cross-section channel velocities for the reach decreased from the Q10 and Q25 to 6 fps due to a significant change in flow velocity at STA 7+00. Overall, average channel cross section flow velocities ranged from 3.0 fps to 9.6 fps. Water depths averaged 2.4 ft and ranged from 2.0 ft to 4.7 ft. Flooding between STA 7+71 and 9+84 appears to be caused by a local depression in the topography and a backwater effect from the grade control at STA 7+00. As flow backs up behind the existing grade control velocity in the channel decreases and causes flood elevations to expand above current top of banks (**Figure 6 and Sheet 2**). Flooding threatens to inundate a carport located on parcel # 037A277301300.

In the lower section of Chimes Creek, the majority of the Q100 flow is contained within existing banks. Flow is predicted to briefly break out of the channel at STA 3+42, and 1+24 however it returns to the channel before the next cross section. Velocity and depth of overbank flow at these locations range from 0.26 fps to 0.30 fps and 0.02 ft and 0.03 ft, respectively.

Overall, no structures are threatened in the lower section of Chimes Creek. Water surface elevations are plotted in **Figure 6** and ranged from 242.8 ft to 214.6 ft at the ACFCD culvert.

Conclusions

A hydraulic analysis helps determine project constraints related to depth, velocity, and flooding patterns of a project site at various flow levels. Flooding in the upper section of Chimes Creek is predicted for all flows exceeding the 2-yr event (120 cfs). During community meetings, residents stressed that flooding in the upper section of the project reach occurs “frequently”. Model results support such claims, showing that watershed wide urbanization has likely increased flow volumes and flooding for even the 2-yr event. Therefore, flooding in the upstream section of the Chimes Creek study reach must be considered as a design constraint in all prospective design alternatives. Finding an acceptable balance between flood control and bank stabilization is a key design consideration. For instance, raising the existing grade control at STA 7+00 or drastically increasing channel roughness with woody debris and wide-scale willow plantings could cause increased flood elevations upstream. However, as indicated in geomorphic analysis, lowering the existing grade control structure at STA 7+00 could potentially increase erosion upstream. Therefore, spot treatments of hand placed bank plantings and willow mattresses may provide the best balance between flood control and ongoing erosion issues between STA 7+00 and 11+50. Fortunately, for the lower section of Chimes Creek, all major channel incision and bank erosion features are located where model predictions show no risk to occupied structures at even the 100-year (198 cfs) discharge.

SECTION 5. CREEK STABILIZATION

General Management and Stabilization Constraints

The management of urban creeks is often a complex balance between multiple and competing interest groups including private property owners, local flood control districts, cities, counties, and state and federal agencies who regulate sensitive species and public resources. Implementation of a successful project requires tailoring project goals, objectives, and designs to meet this complex social structure and specific engineering challenges. Overall, there are four considerations to be made when designing bank stabilization projects:

1. Protection of Private Property and Existing Utilities
2. Flood Control
3. Preservation of Terrestrial and Aquatic Resources (including habitat and water quality)
4. Channel Stability
5. Permitting

When bank stabilization structures are installed, there is potential for erosion impacts to be transferred to other locations along the channel where they can impact private property or existing utilities. Therefore, one of the fundamental concepts of bank stabilization design is to stabilize the bank and channel without moving the erosion problem to another portion of the stream. This is generally done by maintaining to the extent possible the basic channel geometries found within the creek system. This is a key reason why a contemporary geomorphic analysis was completed in this feasibility report. Adhering to the baseline channel geometry observed in the geomorphic analysis will minimize potential impacts to other portions of the channel, adjacent property, and existing utilities. Stabilization designs that do not mimic the existing geomorphic controls and channel dimensions will likely move erosion to other locales and will require reactionary and costly maintenance. Existing utilities along Chimes Creek include a city sewer line that parallels both sides of the channel between STA 2+00 and 9+00 and two storm drains that enter the project reach at STA 5+50 and 7+84. Alternatives should not compromise existing utilities and should include re-alignment and or protection plans if necessary.

Bank stabilization projects alter the longitudinal profile and cross-sectional shape of streams in an effort to halt erosion. Changes in cross-sectional shape can lead to increased flood elevations and increased risk of flooding to adjacent structures. Therefore, all design alternatives should be thoroughly evaluated with respect to their effect on existing flood conditions.

Bank stabilization projects can significantly impact local wildlife species and may require removal of large trees. Alternatives should be developed that minimize impacts to local flora and fauna within the riparian zone and when possible, existing natural vegetation should be incorporated into project alternatives to minimize the loss of large trees whose root structure provides soil strength and canopy cover to various species.

Stabilization projects can reduce the frictional resistance of a channel and transfer the erosive energy downstream of a problem site and cause channel instability. This can occur when vegetation is removed and replaced with concrete rock revetment that prohibits the growth of an adequate vegetation matrix. Therefore, it is essential that biologic or biotechnical, re-vegetative, and woody debris techniques be used to the greatest extent possible. These features increase vegetative and physical roughness in the channel and help dissipate energy gained in an erosion area before it is transferred to other portions of the channel to create erosion problems.

Factors Controlling the Stabilization Solution at Chimes Creek

Stable channels usually have channel dimensions that dissipate fluid forces and can pass the sediment load. Changes in the equilibrium cross-sectional area will likely mean that the energy in the creek will be expended elsewhere in the form of erosion. The challenge is to determine appropriate bank stabilization approaches in the context of an urban stream. Constraints in these situations include adjacent structures, significant riparian trees, and the overall balance in the channel. Normally, creeks would be allowed to shift position and adjust to alterations in the watershed hydrology, sediment transport regime, and riparian vegetation recruitment. In an urban context, typically only a small amount of lateral alignment shift can be tolerated before some type of stabilization or bank armoring is necessary to preserve property and structures.

The lack of residential structures near the top of bank and flood hazards in Chimes Creek make balancing flood control and channel design a minor component of design. Fortunately, the majority of residential structures are set back from the channel and are not threatened by flood waters.

The amount and size of riparian tree canopy also presents an issue where large mature trees at the top of bank, like those observed along Chimes Creek, provide key canopy and shade for the riparian corridor. The large bank top trees have extensive root systems that provide key stability to the banks.

Physical controls on the selected stabilization alternative are critical, however socioeconomic forces often determine which alternative is selected. For instance, the lack of public access to the project site will likely make funding of the final restoration project challenging.

SECTION 6. STABILIZATION TECHNIQUES, ALTERNATIVES DEVELOPMENT & SCREENING ANALYSIS

General Approaches to Stabilization

As noted in the geomorphic analysis, Chimes Creek suffers from rapid incision of the channel bed and subsequent bank failure/erosion due to toe undermining. At a minimum, stabilization and restoration alternatives must incorporate some technique to stop incision and protect existing bank toes from further undercutting. Additional methods can be employed to stabilize banks.

For report discussion purposes, a wide array of potential stabilization and restoration techniques are presented below. Following the general discussion, three conceptual alternatives are proposed which incorporate combinations of the different techniques to meet project constraints. There are many combinations of biotechnical, structural, and hybrid erosion control methods that could be incorporated into the Chimes Creek project design. It should be noted that there is a strong preference to utilize treatments that minimize the use of hard revetments such as rock and concrete and promote vegetative (biotechnical) and non-structural solutions.

Considered but Unpursued Alternatives

Culverting the entire creek was also considered to address maintenance concerns. Though hydraulic effectiveness and low maintenance requirements would be achieved, the loss of existing riparian habitat, loss of aesthetic value of the creek to property owners, and high cost associated with culverting the entire creek would be prohibitive. Additional mitigation for culverting the entire creek would also be required. Typical off-site mitigation ratios range from 2:1 to 3:1 suggesting that up to 4200 ft of stream would have to be restored in another location or off-site conservation easements purchased.

During project scoping meetings with the MHA, residents showed interest in creating a high-flow bypass channel to divert water around the Chimes Creek Project site during high flow events. Construction costs for installing a bypass channel would be similar to culverting the entire reach and would still require large-scale grading (disturbance), construction access along the channel, and full environmental permitting. Additionally, the existing sewer alignment severely constrains the bypass option and realignment of existing utilities should be expected. Finally, installing a bypass or culverting Chimes Creek would do nothing for restoring the geomorphology of the stream or re-establishing the natural riparian vegetation assemblages. Off site hydro-modification was discussed but given the significant constraints with private property and existing storm drainage capacity issues upstream its viability and effectiveness reduced its feasibility. Therefore, culverting Chimes Creek or installing a bypass or hydro-modification were dropped as a viable alternatives. Instead the alternatives presented are geared to arrest the current erosion conditions, provide a suitable stable channel form for the anticipated flows, and restore the existing stream corridor to a more native and appropriate vegetation assemblage.

Applicable Stream Stabilization Techniques

- **Rock Drop Structures (Weirs)** are permeable low check dams comprised of large boulders. Their V-shape planform configuration directs flow towards the center of the channel and promotes scour downstream. Rock weirs can be installed as grade controls to create a slight backwater effect that decreases upstream velocity and promotes sediment deposition. As a grade control, rock weirs are usually keyed 2-4 feet below the predicted scour depth of the channel and because weirs cause flow constriction and downstream scour, plunge pools consisting of an armored rip rap bed are often used in conjunction with this technique. Additional rock toe placement upstream and downstream of the drop structure prohibits flanking of the structure. This channel stabilization method can effectively control knickpoint migration.

- **Roughened Channels** can be constructed where vertical incision of the stream channel is observed. Unlike rock weirs that control grades by stepping down a stream in a series of vertical drops, roughened channels consist of a highly immobile layer of coarse sediment that is determined to be stable under a specific design flow. The coarse layer of immobile is overlain throughout the existing channel and armors against incision.

- **Planted Rock Rip-rap** consists of a specially constructed rock rip-rap structure that has soil and live stakes (usually willows, ninebark, or dogwood) inserted into the open voids or joints between the rock. Design issues include selection of rock size and gradation, depth of toe placement, and height on the embankment which is determined by expected flow velocities, flow depth, and scour depth. The objective is to limit the height of the structure, while also limiting encroachment into the channel. Rock rip-rap is best constructed in stages or lifts working up-slope to allow insertion of soil and live willow stakes. Rock rip-rap can be constructed on slopes as steep as 1.75H:1V, especially if a pipe corral is installed at the toe, to prevent launching.

- **Loose Rock Revetment** consists simply of placement of rock on existing slopes grades with little or no slope preparation. Generally a toe structure is not constructed. The advantage of this method is that rocks can be placed around obstacles such as trees. The disadvantage is that the finished embankment is not as stable as a properly engineered and constructed slope, because of the possible lack of toe support and the fact that frequently the slopes are as steep as 1H:1V. Sometimes pipes are driven into the toe of the channel to provide support for the looser rock. This technique requires careful selection and placement of rock material. As with planted rock riprap, live willow stakes can be inserted in voids between rocks. Loose rock can often be used as a transition structure upstream and downstream from the main bank protection element.

- **Live Staking and Willow Wattling** utilize live cuttings or slips of sprouting and fast growing riparian plants to stabilize bank slopes by buffering flow with above ground foliage, while providing soil stabilization with root growth. Willow wattles (also called live fascines) are long bundles of branch cuttings bound together in cylindrical structures. They are placed in shallow trenches on contour and are principally used to prevent slope erosion and very shallow slumping and rilling**.** Since these techniques rely on rapid plant growth for stabilization, they are best used on sunny sites, or in combination with erosion control blankets at most bank repair sites. Live staking and willow wattling can be installed by hand and are excellent methodologies for the upper section (STA 7+00 – 11+50) of Chimes Creek.

- **Erosion Control Fabric Planted with Rooted Trees/Shrubs** involves preparing a smooth surface along the upper bank, seeding with grass and appropriate fertilizer, and covering this surface with an appropriate biodegradable erosion control fabric. The erosion control fabric provides temporary protection against surface rilling and gullying while the grass becomes established and, when properly installed and stapled to the ground, can provide protection against scour from high stream flow. Rooted native trees and shrubs, selected based on the sun and water availability on the bank, are planted through the erosion control fabric at relatively close spacing. These plantings are then irrigated periodically for several years until they become permanently established and can be counted on for permanent scour protection for the upper bank. This is one of the most labor-intensive upper bank protection techniques and is the preferred alternative for projects where toe erosion or stream velocities are not high or where equipment access is poor such as the upstream sections (STA 7+00 – 11+50) of the Chimes Creek project reach. At some locations, use of rock toe protection is needed with this technique.

- **Large Woody Debris** plays an important role in natural systems. In natural conditions, woody debris in east bay streams provide channel bed stability by creating temporary channel bed erosion control and sediment traps. Large woody debris falls into the channel from erosion. It makes a temporary blockage for smaller debris and sediment thus reducing the bed slope upstream. It creates a local grade control by reducing the sediment transport which leads to reduce channel degradation over the long-term.

- **Brush Mattress** is a combination of live stakes (usually willow), live fascines or willow wattles, and branch cuttings installed to cover and stabilize eroding stream banks. They are usually twine or wire constructed and held in place using stout stakes as a sort of cross-laced grid system to hold the brush down until some of it begins to sprout. This method can be used to form a live armor against fast-flowing water with abrasive power, but is less effective in combating toe scour or slumping. The brush layer is usually cross-tied to the slope using stakes and rope or wire. Adequate channel flow capacity must also exist. This technique is best used where banks are not particularly steep or high and would be an excellent bio-technical technique for the upper section (STA 7+00 – 11+50) of Chimes Creek.

- **Coir Fiber Rolls/Fiber Rock Rolls/Coir Erosion Blankets** are cylindrical structures filled with coconut husk fibers bound together with twine woven from coconut (Figure 18). They are available in 12- or 18-inch-diameter sizes and 10- to 20-foot lengths. Fiber rock rolls are similar, except that the twisted twine encasement is constructed of long-lasting synthetic rope and the structure is filled with rounded stream cobbles, sometimes available on site. Often several rolls are stacked atop each other with the lowest structures composed of rock rolls buried in a trench and anchored using hooked rebar, with fiber rolls (sometimes called biologs) placed atop. These structures are very flexible and adaptable, conforming to irregularities of the bank with little need for excavation and site disturbance. The fiber rolls can also be used to transition upstream and downstream from planted rock riprap sites. Often they can be entirely constructed using hand labor. Live willow stakes are inserted through or between the rolls, which gradually degrade as they trap sediment. Many times a biodegradable erosion blanket and live willow staking is used on the slope above the roll-stabilized toe. This alternative should often be used as a transition between harder techniques and upstream/downstream unprotected banks.

- **Coir Bio-D-Blocks** are biodegradable structures of densely-packed coir for stabilizing streambanks. Coir blocks are available in heights up to 1.5 ft and can be stacked nearly vertical along channel toes. Willow or other riparian plantings are inserted between each block and eventually establish scour resistant root systems that deter toe undermining and subsequent bank failure.

- **Soil Lifts** are composed of biodegradable coir erosion blankets wrapped around existing soil or substrate along channel banks. The resulting structure looks similar to large pillows and can be stacked upon one another and planted with willow or riparian cuttings.

Alternatives

Questa has developed three alternatives, 1) **Elevated Grade Restoration**, 2) **Rebuild and Stablize Bed/Erosion Areas** and 3) **Roughened Biotech**, which are discussed and then screened below using project constraints. All project alternatives share some features due to the commonality of the major erosion types and geomorphic constraints that need to be addressed (**Table 9**). These alternatives are generally scaled in cost and amount of construction reconfiguration and disturbance.

- **Alternative 1 “Elevated Grade Restoration”**

The distinguishing feature of the first alternative is the installation of five elevated rock drop structures and channel bottom fill between STA 0+00 and 7+00. This alternative will widen the channel, and grade adjacent channel banks to a slope of 1.5:1 (H:V). A combination of planted rock rip-rap near grade controls and coir fiber rolls along the toe of the channel to prevent lateral scour during high flow events will be used (**Sheets 5 and 6**). Rock weirs will control vertical incision and knickpoint migration and manually installed biotechnical measures such as planted coir rolls and erosion blankets will be used upstream (7+00-11+45) to treat minor erosion areas. **Alternative 1** will require grading back the existing channel banks and the extent of grading is depicted in **Sheets 5 and 6**. The entire channel bank (0+00-11+45) will then be replanted to provide a riparian assemblage more in sync with natural conditions.

The hydraulic and geomorphic analyses suggest a 9-ft wide bankfull channel could be constructed with alternating pool and riffle habitat on outside bends of a 3-ft wide low flow channel. The proposed planform shape of **Alternative 1** will follow the existing conditions alignment to limit potential transfer of erosion areas to downstream locations. Sinuosity of the channel will be increased slightly in the straight portions of the channel. Trees and woody material unearthed during construction and supplemented with imported woody debris if necessary would be placed at key locations along the channel to increase roughness and decrease velocities during high flow events and provide heterogeneous habitat structure. Overall, **Alternative 1** is a comprehensive re-engineering of channel profile and cross sectional shape with a cost of $550,000-$670,000.

- **Alternative 2 "Rebuild and Stabilized Bed/Erosion Areas"**

The second alternative installs seven strategically placed rock drop structures and bio-technical bank stabilization along channel banks between STA 0+00 and 7+00 (**Sheets 7 and 8**). This alternative will not increase channel elevations through the addition of fill. Drop structures would be installed at current profile elevations to control vertical incision and adjacent channel banks would be re-graded only where construction access is limited and where severe erosion sites require it. Additionally, manually installed biotechnical measures such as planted coir rolls and erosion blankets will be used upstream (7+00-11+45) to treat all minor erosion areas. The proposed extent of grading in the lower section (0+00-7+00) for **Alternative 2** is shown on (**Sheets 7 and 8**). Banks cut back and graded for construction site access would be covered with a combination of brush mattresses, erosion control blankets, and native riparian plants. The toe of the outside bend in the channel would be lined with coir logs to prevent further undercutting of banks and willow planted rock toe would be installed approximately 15-20 feet upstream and downstream of proposed grade controls. Cost of this alternative is estimated to range from $400,000-$490,000.

- **Alternative 3 "Roughened Biotech"**

The third alternative targets vertical incision in the lower section (0+00-7+00) by augmenting the channel bed sediments by placing a layer of larger stone on the bottom of the channel in a 16- to 18-inch thick layer. This layer of stone would be comprised of slightly angular to rounded river stone with an appropriate finer grain matrix. This bed augmentation would likely provide a more suitable substrate for the algal based benthic environment. The lower 2 to 3 feet of bank toe would be protected from toe undercutting with coir logs or blocks along outside bends. The roughened channel will be constructed using appropriately sized rock that is determined to be stable at the 25- to 50-yr flood event. Woody debris elements would be placed every 150 to 200-feet and keyed into the channel bottom to provide additional roughness to the channel. Minor grading and stabilization will be performed only where construction access necessitates widening of the channel. In addition to the roughened bed, willow plantings (waddles and poles) will be used in conjunction with the Coir logs to establish root binding. (**Sheets 9 and 10**). Cost of this alternative is estimated to range from $257,000-$315,000.

Table 10

Summary of Alternatives

Screening Criteria	Elevated Grade Restoration Alternative 1	Rebuild and Stabilize Bed/Erosion Areas Alternative 2	Roughened Biotech Alternative 3
Rock Drop Structures	√	√	
Coir/Fiber Logs/Blocks	√	√	√
Planted Rock Rip-Rap	√		
Channel Grading	√	√	√
Minor Bank Grading/Stabilization	√	√	√
Engineered Banks	√		

Large Woody Debris	√	√	√
Native Riparian Plantings	√	√	
Channel Fill	√		√
Erosion Control Fabric	√	√	√

SECTION 7. ALTERNATIVES COMPARATIVE ANALYSIS AND SCREENING

This section reviews the advantages and disadvantages of the various project alternatives with respect to each other. There are six main categories that the project should be reviewed under;

- Flood Control
- Protection of Property and Existing Utilities
- Environmental Impacts (Habitat and Water Quality)
- Channel Stability
- Permitting
- Cost

Flood Control

Generally, the design of alternatives should not create an increased water surface elevation that causes increased flood risk and damage. Preliminary site visits and documented flood events by residents suggested the upstream section (7+00-11+45) has the greatest risk of flooding. Therefore, none of the alternatives would increase water surfaces to a point where flooding of structures would be a concern.

Protection of Property and Existing Utilities

The goal of each of the proposed project restoration alternatives is to protect property and the existing utilities in the channel. **Alternative 1** has the lowest risk and **Alternative 3** the highest. **Alternative 1** provides the most amount of protection because it is generally proposing a complete channel reconstruction and semi-restoration of the historic channel bed. Larger amount of rock and bio-technical erosion control products would be used to provide long-term stability. **Alternative 2** stabilizes the bed but only addresses bank slope erosion in a minor way. Some areas of bank erosion would be stabilized but other less severe areas would not. In the long–term it would be expected to see some bank erosion in those untreated areas but it would not likely threaten any structures. **Alternative 3** only augments the channel bed with rock, constructs woody debris structures and treats half of the channel bank toes with biodegradable coir products. This alternative may not completely arrest vertical bed degradation but will significantly slow its progression. Under **Alternative 3** property owners would continue to see some bank slope erosion but at a slower rate and banks could be stable for numerous years after construction.

Environmental Impacts and Restoration

This category generally takes into account potential environmental impacts to the existing creek channel and future restoration potential. **Alternative 1** will have the largest short term environmental impacts including the possibility of reduced water quality from exposed graded slopes. However, it will also have the greatest opportunity to remove exotic vegetation and restore the corridor to a more native Californian riparian vegetation mosaic in the long term. **Alternative 2** will have less of an impact on the existing creek channel and water quality primarily because of reduced grading and construction activities. The impacts would be limited to the channel and some adjacent bank slopes. This alternative does provide for some restoration and habitat improvements but much of the existing exotic plant and tree species would remain. **Alternative 3** would have limited impacts to water quality, habitat, and the overall creek corridor. The impacts would be limited to the immediate channel bottom and side slopes and much of the work would be completed by small equipment and hand crews. The addition of a rocky substrate will likely benefit the establishment of algal based food web and could increase the primary productivity of the system.

Costs

A summary of estimated construction costs for all alternatives is provided in **Table 11**. Values presented are for planning level type analysis and comparison. If the goal is to stabilize both the vertical degradation and the bank slopes, then **Alternative 1** provides that with little or no reasonable long-term erosion risk. **Alternative 2** primarily provides for the stabilization of the vertical degradation, so some lateral movement and channel widening will continue in the long-term. **Alternative 3** seeks to manage the problem at a minimum of cost and impact.

Costs for all three alternatives vary widely due to the specific engineering elements in each design but can be separated into two categories; Site Work and Design and Construction. Typical costs for “Site Work” include mobilization, site superintendence, water diversion, demolition, grading, imported fill, revegetation, and erosion control. “Design and Construction” costs include creation of detailed plans and specifications, permitting, biological monitoring, and construction management. “Site Work” typically makes up 60% of project costs while “Design and Construction” make up the additional 40%. Permitting costs include attaining the all required permits (CEQA, RWQCB, CORPS, City of Oakland) necessary for construction (See Section 8).

Table 11

Alternative Cost Summary

Alternative 1	\$550,000 - \$670,000
Alternative 2	\$400,000 - \$490,000
Alternative 3	\$257,000 - \$315,000

Permitting Considerations

All work within ordinary highwater of the Chimes Creek channel would be in the jurisdiction of the U.S. Army Corps of Engineers (Corps). The Corps would initiate consultation with the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) regarding potential threatened and endangered species issues. All of these agencies would be concerned with impacts to the general health of the creek system, special status wildlife present in the area, and aesthetics of the channel. Special plans and procedures will have to be implemented to ensure that temporary construction impacts are minimal. It is also unlikely that a Habitat Mitigation and Monitoring Plan (HMMP) will have to be developed and implemented to fulfill permit requirements for at least Alternatives 1 and 2. All alternatives will require permits from the Corps. due to the modification of channel planform, grading, and installation of rock drop structures involved. Permits for both CDFG and RWQCB are also very likely regardless which alternative is chosen. Permitting requirements are discussed further in Section 8 of this report.

Evaluation Matrix Comparison

The three alternatives presented are combinations of the wide range of potential restoration activities available for bank stabilization within Chimes Creek. Various hybrids of the activities presented can be substituted into the alternatives to create new alternatives which can complement various budgets and other constraints and stakeholder priorities. The three alternatives are to be viewed less as equal and separate options, but more as three approaches which can build upon one another. We have developed a matrix table below that summarizes the alternative in respects to evaluation categories (**Table 12**).

Table 12

Alternatives Screening Analysis Summary

Screening Criteria	Elevated Grade Restoration Alternative 1	Rebuild and Stabilize Bed/Erosion Areas Alternative 2	Roughened Biotech Alternative 3
Property/UtilitiesP rotection	Highest - Stabilizes Both the bed and Bank Slopes	Medium - Stabilizes the bed and Repairs Some Side Slopes	Medium/Low - Reduces the Rate of Incision and Erosion Processes.
Flood Control	Increased Flow Conveyance. Slight changes to Flood Levels but no impact on existing structures.	Increased flow conveyance, No impact to Flood Levels.	Increased Flow Conveyance, No Impact to Flood Levels.
Environmental Impacts	High-Large Sections of Creek Corridor Will be Graded and Rebuilt.	Moderate-Temporary Impacts During Construction.	Moderate/Low - Temporary Impacts During Construction.
Habitat	High Short Term Impacts to Habitat. Large Long Term Benefits to Natural Flora and Fauna via Restoration of Natural Riparian Community.	Moderate Short Term Impacts. Improved Long Term Habitat Conditions via Removal of Exotics and Planting of Native Flora.	Little Short Term or Long Term Improvement of Habitat Conditions. Current Non-Native Species left Along Riparian Corridor.
Water Quality	Highest Risk of Short TermWater Quality Degradation by Exposure of Graded Slopes During Construction Through Plant/Seed Establishment.	Moderate to Low Short Term Risk of Water Quality Degradation Associated With Minor Grading and Bank Stabilization.	Lowest Risk to Short Term Water Quality Degradation Caused Primarily by Grading in the Channel.
Duration of Protection	Highest- Provides Greatest Short and Long Term Protection.	Moderate- Provides Long Term Reduction of Incision. However Short Term Protection is Limited. Some Channel Banks Will Continue to Fail.	Lowest- Provides Short Term Reduction of Incision Processes. Additional Bank Failures Will Continue at a Reduced Rate.
Channel Stability	Most Stable of Alternatives. Vertical Incision and Channel Bank Erosion Controlled.	Vertical Incision Controlled. Some Lateral Channel Adjustment and Bank Slumping Will Continue.	Small Improvement, Incision and Erosion Rate Reduction
Permitting	Full permitting Required	Full Permitting Required	Full Permitting Required
Cost	$550,000 - $670,000	$400,000 - $490,000	$257,000 - $315,000

Next Steps
The next step in the design evaluation process is to provide feedback on the alternatives presented here in this report, adopt a preferred project and develop a final plan set.

SECTION 8. SCHEDULING AND PERMITTING

This section provides a background on permits and scheduling required for the implementing the selected alternative. Project scheduling has been organized into 4 steps.

<u>Step 1. Local, State and Federal Agency Permitting and Project Approval</u>

Obtaining all necessary regulatory approval for bank stabilization work near or within streams has historically been a time-consuming and often confusing process. By law, a project usually requires approval from a number of agencies. This section is intended to clarify this process.

While agencies with jurisdiction over stream projects will not waive their responsibility to review project plans before construction, the strategy employed here is intended to help facilitate the review process involving coordination between the City/landowners and all regulatory agencies. If these guidelines are followed, many of the questions, as well as design backup, will be provided to regulatory agencies. Given this framework, it is likely (though not impossible) that the project will not stall in the approval process and will be approved in a reasonable amount of time, with minimal changes to the plan. The City will reserve the right to request modifications to privately proposed projects, or reject those that they do not consider as appropriate and consistent with this report.

Several federal, state, and local agencies have responsibilities for the protection of wetlands and creeks in the San Francisco Bay area. The U.S. Army Corps of Engineers (Corps), California Department of Fish and Game (CDFG), and the Bay Delta Regional Water Quality Control Board (RWQCB) all require permits and/or approvals for projects that may affect wetlands and creeks, including stream bank stabilization projects.

U.S. Army Corps of Engineers (Corps) 404 Permit - The project proposes removal and/or placement of materials in the stream area, so the applicant must apply to the Corps to determine if a Section 404 permit is necessary, pursuant to the Clean Water Act. If a federally listed endangered species is potentially found on the site, the Corps must consult with either or both the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS). These agencies must review and comment on the application prior to its approval. Either of these agencies has the ability to request more information or changes in project design and mitigations.

Endangered Species Act **-** The USFWS and the NMSF enforce the federal Endangered Species Act (ESA) rules that prohibit the "take" of listed species through human activities. "Take" means destroying a species ability to breed, feed, or find shelter, and includes take as result of erosion/siltation, landslide, mudflow, or bank failure from a poorly designed and executed management action or construction project. The NMFS enforces the ESA for marine fish. The principal species of concern of the USFWS along stream corridors is the red-legged frog, but there are other species of concern that also must be considered. In its permit processing, the ACOE will contact USFWS and/or NMFS to determine whether a proposed activity may impact a listed species. Legally it is up to the applicant to show that species are not impacted, and if the Corps is not involved in the permit processing under a Nationwide Permit, or a Regional Programmatic permit, then the landowner must contact the USFWS or NMFS directly.

Department of Fish and Game Code Section 1601/1603 - The Department of Fish and Game Code section 1602 requires any person, state or local governmental agency, or public utility to notify the CDFG before beginning any activity that will do one or more of the following: 1) substantially obstruct or divert the natural flow of a river, stream, or lake; 2) substantially change or use any material from the bed, channel, or bank of a river, stream, or lake; or 3) deposit or dispose of debris, waste, or other material containing crumbled, flaked, or ground pavement where it can pass into a river, stream, or lake. Fish and Game Code section 1602 applies to all perennial, intermittent, and ephemeral rivers, streams, and lakes in the state. Therefore, a Lake or Streambed Alteration Agreement (LSAA) is likely required for any stream bank stabilization project conducted under the guidance of this document.

Regional Water Quality Control Board Water Quality Certification **–** The Porter-Cologne Water Quality Control Act (Porter-Cologne) gives the State Water Resources Control Board the ultimate authority over water rights and water quality issues. The Porter-Cologne established nine Regional Water Quality Control Boards (RWQCB) to oversee water resources of the state. Regional boards regulate local pollutant discharges that may impact all surface and groundwater resources in their region. This includes the issuance of waste discharge requirements or waivers for discharge for any restoration projects that may affect water quality. Furthermore, Section 401 of the Clean Water Act requires that RWQCBs determine consistency among (Water Quality certification or waiver) proposed projects with California water quality laws, and certain sections of the Clean Water Act. Restoration of Chimes Creek will require approval from the Regional Water Quality Control Board.

City of Oakland Creek and/or Alameda County Grading/Building Permit - A local permit issued by the City or County is required for any excavation or fill that will encroach on or alter a natural drainage channel or water course, including adjacent floodplain areas. In addition, some kinds of structural stabilization approaches, such as a live crib walls require a building permit.

California Environmental Quality Act (CEQA) - Any time permits are required to be issued by the City, County, the CDFG, RWQCB, or ACOE, an environmental review is necessary. Depending on the specific project parameters, a Negative Declaration, a Focused Expanded Initial Study/Mitigated Negative Declaration, or focused Environmental Impact Report (EIR) may be required. However, certain repair, replacement, and small restoration projects similar to the proposed Chimes Creek Alternatives may be “Exempt” from environmental review. The City of Oakland is responsible for completing the CEQA review of projects and to determine which CEQA documents are required. Final project descriptions and plans should be submitted to the planning department for this review.

Step 2. Preparation and Submittal of Construction Plans and Specifications

Preparing formal Plans and Specifications, including the Engineer's Estimate of Probable Costs, will help ensure that the constructed project meets all of the project Goals and Objectives and considers all of the regulatory requirements and design constraints. The Plans and Specifications should include the following:

- Contractual language, including method of measuring work for payment, and applicable unit and lump sum costs, bonds, and retentions;
- Method for change orders and payment provisions for unforeseen circumstances;
- Construction schedule and any penalties for delayed work;
- Detailed description of the Scope of Work;
- Materials specifications and suppliers list;
- Construction methods, tolerances and work requirements;
- Access, right-of-way, utilities, limits of work, mobilization and staging areas;
- Plan sheets, details, and typical cross sections; (following City/County Engineering Standards);
- Notifications, submittals, and construction inspection;
- Regulatory requirements, permit conditions, and work restrictions;
- Plan for water diversion and de-watering, and construction erosion control (SWPPP);
- Plan for protection or relocation of sensitive aquatic vertebrate species and fish;
- Post- construction (3-5 yr) adaptive management, monitoring, and maintenance contract.

Step 3. Construction Observation, Inspection and Monitoring

For large stream bank repair, stabilization, and revegetation projects, on-site construction inspection could be performed by City or contract inspectors. This could include both public projects and privately constructed projects. The purpose will be to interpret plans (for public works projects), to ensure that the project plans and specifications are followed, and that sensitive areas, including any sensitive species, fisheries and water quality protection measures are correctly implemented according to the conditions of the permit and approved project plans.

The City/County inspectors will ensure that appropriate construction quality control procedures are followed and documented for the record. This is especially important for construction contractors not familiar with biotechnical bank stabilization methods, which often cannot be specified to the same level of detail as more traditional bank stabilization projects, and may require more field adjustments and field decisions. Proper location, handling, and installation of structures and plant materials are critically important, and the project designer may need to provide on-site direction, as they are most familiar with the construction design intent. The construction inspector will also need to resolve problems with specifications and materials, approve changes, and deal with unforeseen problems and difficulties, particularly any geotechnical and drainage problems uncovered during soil excavation and foundation preparation. Any field changes should be documented in a project As-Built Plan.

Construction site erosion control, stream diversion, and water handling methods should be a main focus of the review and construction inspection. For public projects, the City or County will normally have a project biologist/monitor that will assist in construction observation and ensure that appropriate water quality, wetlands, and sensitive species protection protocols are being followed. The City, County, or other regulatory agencies may also require a biologist/monitor be on site for private construction projects. The City/County inspector and project biologist/monitor will be given the authority to shut down or suspend work at a project site as appropriate if the terms of the construction plans and permit conditions are not being followed. If historically or archaeologically significant objects are uncovered, the City and County will also normally shut down a project until an expert review by a qualified archeologist is completed and appropriate recommendations and mitigations are developed.

It is emphasized here that the construction contractor is responsible for complying with all permit conditions relating to erosion and sediment control, traffic and job site safety, and compliance with regulatory permit conditions, especially those relating to the Endangered Species Act.

Step 4. Post-Construction Maintenance and Monitoring

A program of observation, monitoring, maintenance, and management is very important to ensure project success for vegetative and biotechnical designs which depend on successful plant establishment for erosion protection and bank stabilization. Most repair project sites should be visited, inspected for damage and planting success, and photographed following all major storm flows, and at least monthly during the first growing season. Replanting, maintenance of the irrigation system, weeding and pest control, and re-securing erosion blankets and fiber rolls may be necessary, as well as other work such as additional rock placement, filling any voids with smaller rock and soil, and joint planting additional willows and other woody species.

A minimum three-year maintenance contract should be included in the construction contract for large public bank stabilization projects, particularly those that utilize vegetative and biotechnical approaches. The City/County may also require private parties to contract with a biologist or landscape contractor to monitor and maintain the restoration and stabilization site's irrigation and landscaping/ native plantings.

Often the permit conditions issued by the regulatory agencies will require submittal of a Habitat Mitigation and Monitoring Plan, which will outline maintenance and monitoring protocols, times, and methods, and provide specific success criteria against which the monitoring results are to be judged.

SECTION 9. REFERENCES

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